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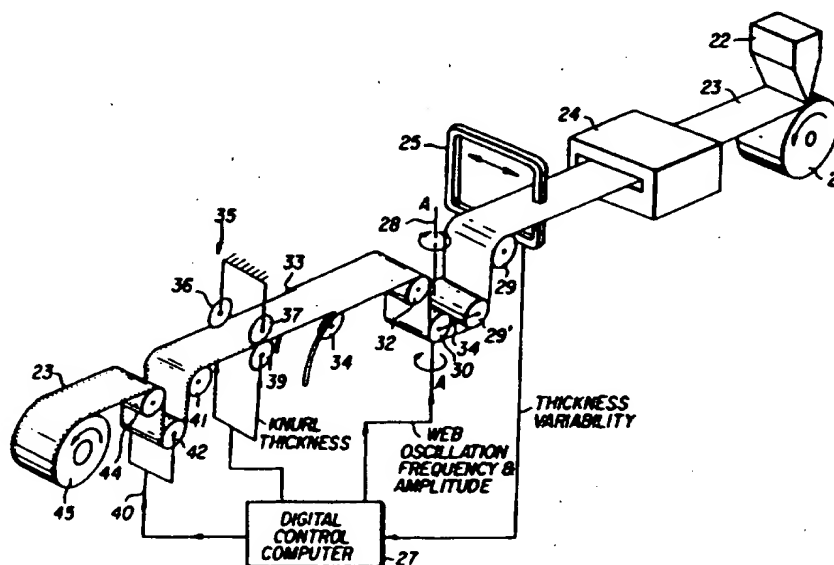
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(54) Title: **CONTROL OF WEB WINDING**



(57) Abstract

In the winding of webs of plastic films, defects in the web caused by hard streaks in the wound roll are avoided or reduced by a new method of control. In this method, measurements are made of elastic properties of the web and of the average widthwise thickness distribution of the web. From these values and from selected initial winding conditions, including web tension, edge thickness and web oscillation conditions, potential web defects are predicted. These are compared with acceptable tolerances and, if excessive, the winding conditions are optimized to reduce the predicted web defects and the next roll is wound under such optimized conditions.

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1
CONTROL OF WEB WINDING

Field of Invention

- 5 This invention relates to the winding of plastic webs and, more particularly, to a method of controlling web winding to avoid or reduce the creation of defects in the web.

10 Background

- Plastic webs such as photographic film bases, that are made by continuous extrusion or melt casting, often exhibit widthwise thickness variations (distribution of thickness across the width of the web) which are persistent in the lengthwise direction. These thickness variations are sometimes called gauge bands or thick/thin streaks. When webs having such gauge bands are wound into rolls, hardstreaks (also called ridges) can form in the winding roll. Hardstreaks are annular bands in the winding roll that are parallel to the sidewall of the roll. Where hardstreaks occur the diameter of the winding roll is increased and the pressure between layers in the wound roll is concentrated in this area. Hardstreaks are objectionable because they can lead to web imperfections including: distortions, pressure damage to sensitive coatings and adhesion or blocking of adjacent layers or laps in the wound roll.

- To minimize the effect of such thickness variations, both edges of the web can be thickened through an embossing or knurling process and/or the web can be oscillated laterally during winding. Knurling creates artificially thickened areas at the edges of the web which, upon winding, create intentional hardstreaks at the edges. By creating these artificial hardstreaks at the edges in the nonusable portions of the web, a substantial part of the winding tension is used up and

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the effective tension in the middle portion of the web is significantly reduced, thereby reducing the severity of any hardstreaks which may form in the usable middle part of the web.

5 Oscillation, as in U.S. Patents Nos. 2,672,299 and 4,453,659, offsets any thickened portions of the web to reduce the build up of thickness in a particular lateral portion of the wound roll. Although oscillation (also called "wiggle-winding" and "stagger winding") can
10 reduce the development of hardstreaks in the wound web, it can also cause an undesirable amount of edge waste if the oscillation amplitude is large. On the other hand, if the oscillation amplitude is not sufficiently great, the gauge bands in the web are not offset enough to
15 prevent or reduce the formation of hardstreaks.

 Although thickening the edges can reduce the hardstreak problem, if they are too thick, i.e., if the "knurl height" is too great, other problems are caused. Thus, if the edges are too thick, the web will be
20 supported solely at the thick edges and buckling will occur in middle of the roll. Also, if all of the roll tension is carried at the edges of the web, the high pressure at the thickened edges can result in "telescoping" or lateral shifting of laps of the roll
25 because of instability in the widthwise direction. Therefore, to reduce the hardstreak problem without creating other problems it is necessary to determine an optimum edge thickness or knurl height for the web.

 Similar considerations apply to the tension in
30 the web during winding. Although lowering of tension can reduce hardstreaks, if the tension is too low other problems occur. In particular, at excessively low tension a slippage between layers occurs, a problem known in the art as cinching. Likewise, excessively low
35 tension can cause telescoping or roll shifting.

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The described problems can occur in the winding of a wide range of plastic web sizes. The problems are especially serious, however, in the winding of wide plastic webs, e.g., 40 to 80 inches in width, to form large rolls, e.g., of 1.5 to 5 feet in diameter, and especially when the web comprises a thermoplastic film base or support which is coated with one or more photographically sensitive layers and other layers. Such webs are especially susceptible to hardstreak formation, and the waste created by hardstreaks is especially costly. As a consequence a need exists for a method for controlling the winding of plastic webs so that the severity of hardstreaks in the wound web can be minimized without creating other problems.

15

Brief Summary of the Invention

In accordance with the present invention a method is provided for controlling web winding which reduces or eliminates the mentioned problems, especially for wide webs and rolls of large diameter as indicated above. The novel method includes steps which are carried out by automatic data processing equipment employing an analytical model which predicts winding imperfections and facilitates selection of optimum winding conditions to minimize the severity of winding imperfections. Variables which are factors in the model include thickness variations of the web, the winding conditions, dimensions and stiffness of the core, and elastic properties of the web.

25

The method of the invention comprises:

measuring properties of a plastic web to be wound on a core including:

- (a) modulus of elasticity of the plastic,
- (b) stack-wise compression modulus of the

30 web,

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(c) stack-wise compression modulus of the thickened edges,
(d) Poisson's ratio of the plastic, and
(e) stress relaxation modulus of the web;
5 selecting values for at least one of
(a) initial web tension,
(b) initial edge thickness, and
(c) initial web oscillation,
measuring widthwise thickness variations of
10 said web at lengthwise locations on the web,
averaging the measured widthwise thickness variations in the lengthwise direction to obtain an average widthwise thickness distribution for the web,
measuring the core modulus and the width and
15 diameter of the core,
predicting the severity of winding imperfections, from the relationship of (1) said properties, (2) the thickness distribution, (3) the values of initial web tension, initial edge thickness
20 and initial web oscillation, and (4) the measurements of the core, preferably in accordance with the analytical model shown in Figs. 3a and 3b, the parameters of which are defined in Table I;
comparing the predicted imperfections with
25 predetermined tolerances to determine whether the imperfections are within or exceed the tolerances;
when said predicted imperfections are within the tolerances, winding the web on the core at said initial web tension, edge thickness and web oscillation;
30 and
when said predicted imperfections exceed the tolerances, winding the web on the core under corrected conditions including adjustment of at least one of
(a) web tension, (b) edge thickness and (c) web
35 oscillation.

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The Drawings

Fig. 1 is a diagrammatic view in perspective of a wound roll of a plastic film web having knurled edges and exhibiting hard streaks in the roll and distortions 5 in the film surface;

Fig. 2 is a diagrammatic view of a line for extruding and winding a plastic film web, with controls of the winding conditions in accordance with the invention;

10 Fig. 3a is the first part of a flow chart of the analytical model for predicting web imperfections;

Fig. 3b a continuation and completion of the flow chart of Fig. 3a;

15 Fig. 3c is the first part of a word description flow chart corresponding to Fig. 3a, which explains the programming of the model;

Fig. 3d is a continuation and completion of the word description flow chart and corresponds to Fig. 3b;

20 Fig. 3e is a schematic diagram of the method of the invention which uses the analytical model of Figs. 3a-3d;

Fig. 4 is plot showing a widthwise thickness distribution of a film web; and

25 Figs. 5, 6, 7 and 8 are predicted plots of the widthwise radius variations for a roll of film wound under three different combinations of winding conditions at different stages in the winding of the roll.

Detailed Description of the Invention

30 Definitions:

(a) "modulus of elasticity of the plastic" means the ratio of stress to the corresponding strain (lb/in²).

35 (b) "compressive elastic modulus of the web" means the modulus of a stack of sheets of the web material in compression (lb/in²).

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(c) "compressive modulus of the thickened edges" means the modulus of a stack of the knurled or thickened edges (lb/in²).

(d) "Poisson's ratio of the plastic" means the ratio of the contraction of the lateral dimensions of the sample to the strain or unit elongation (elongation per unit of length). This ratio, c/s, is constant for a given plastic material within the elastic limit.

(e) "core modulus" is an expression of the radial stiffness of the core at its periphery, as defined by Equation 8 of Hakiel, TAPPI Journal, Vol. 70, No. 5, p. 114 (May 1987) (lb/in²).

(f) "stress relaxation modulus of the web" means the time-dependent value of stress divided by the constant strain for a stretched sample of the web (lb/in²).

In the method of the present invention, winding imperfections caused by lengthwise persistent widthwise thickness variations are avoided or reduced by the use of an analytical model in either an off-line or an automated on-line calculation to select optimum winding process conditions. The method is carried out under winding conditions determined by a computer that is programmed in accordance with Figs. 3a and 3b.

One step in the computerized method is to obtain multiple measurements of widthwise thickness variability of the web, preferably on-line with a non-contacting device, and averaging these measurements in the lengthwise direction to obtain an average widthwise thickness distribution.

Web properties, including lengthwise modulus of elasticity in tension, stack-wise compression modulus, Poisson's ratio and stress relaxation modulus of the web in tension, are also measured and input into the analytical model. The dimensions of the core (length and diameter) upon which the web will be wound are also

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input. In addition, starting values for the winding conditions, including winding tension, knurl or edge thickness of the web and web oscillation conditions, are selected, usually based on values for a previously wound
5 roll.

Once this information is available and prior to winding the roll, the model is executed and the severity of the winding imperfections is predicted, including distortions, pressure damage to sensitive coatings and
10 adhesion.

The predicted imperfection severity is compared with the predetermined tolerances for these imperfections. If the severity is acceptable, i.e. within the tolerances, the initial winding conditions
15 are used to wind the roll and the process is repeated for the next roll. However, if the predicted imperfections are outside of the tolerance range, the following corrective action is undertaken.

An optimization routine is invoked, such as
20 linear programming, which uses the combined value of the severity of all of the imperfections as the function to be minimized. This routine evaluates the combined value of the severity of all of the imperfections at numerous values of winding tension and knurl height in order to
25 find the optimum combination which results in the minimum value of imperfections severity. Once such minimum is found, the corresponding values of winding tension and knurl height are used to wind the roll, the initial values are updated with the new values and the
30 process is repeated for the next roll. Such linear programming is well known as exemplified by the disclosure in Chapter 10(10.8), pp. 312-326 of "Numerical Recipes, The Art of Scientific Computing" by Press et al., Cambridge University Press (1986).

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To illustrate how this new procedure can be applied to a particular web winding operation, reference will be made to the drawings.

As shown in Fig. 1, a roll 10 of a polyester plastic film 11 is wound on a metal or plastic core 12. Extending along each edge of the film 11 are thickened areas or knurls 13 and 14. Fig. 1 represents a roll in which, because of the winding conditions, defects have been created in the roll and in the surface of the web. The roll defects are the hardstreaks or gauge bands 15 and 16. These are annular portions of the roll of substantially greater diameter than the rest of the roll.

A result of the formation of the hardstreaks 15 and 16 is that the web in the area of the hardstreaks is under excessive radial pressure. As Fig. 1 shows, this results in web defects. These are depicted in Fig. 1 as distortions 17, which can take the form of a line of intermittent, closely spaced dimples, puckers or dents in the surface of film 11. By the method of the present invention the creation of such defects is reduced or eliminated.

Fig. 2 illustrates a film casting line in which the method of the invention can be carried out. The method is schematically presented in Fig. 3e. Roll 21 of the line is a casting or quenching roll on which a polymer film is melt cast by means of an extrusion die 22. Molten polymer, e.g., film-forming poly(ethylene terephthalate), is extruded via die 22 onto the cooled, rotating roll 21 where it solidifies to form the film 23. The latter then passes through one or more selected processing stations which are represented schematically by block 24. These can include any of a number of processes such as film drafting and tentering, heat setting, coating of the film with photographic layers or the like and drying.

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After the processing steps of block 24 where the web achieves its intended thickness prior to winding, the film is subjected to thickness measurements. Although in the method of the invention 5 the thickness measurements can also be made off line on samples of the film, Fig. 2 depicts the embodiment in which on-line thickness measurements are made.

Fig. 2 shows the widthwise thickness measurements of the film being made continuously by 10 traversing the measuring head across the web as the web passes through the instrument 25. The latter can be any of a number of contacting or non-contacting instruments for measuring film thicknesses. A preferred instrument is the Beta-Gauge Basis Weight Sensor of Measurex 15 Corporation, Cupertino, California 95014, Model 2201/2202. This instrument measures the film thickness by sensing variations in Beta-ray transmission by the moving web. The lateral measurements are averaged in the lengthwise direction by the measuring 20 instrument to obtain an average thickness distribution of the web. The values for the average thickness measurement, with other data, are input to the digital control computer 27 as shown in Fig. 2, which computer is programmed in accordance with Figs. 3a, b, c and d.

25 In the method of the invention, at least one of the winding conditions is adjusted or controlled to levels which avoid the formation of hardstreaks in the wound roll or reduce their severity to within acceptable tolerances. These adjustable winding conditions include 30 the tension that is maintained in the web 23 during winding, the height of the thickened edges or knurls that are formed along the edges of the web and the extent to which the web is oscillated as it travels toward the winding roll. See Fig. 3e.

35 In Fig. 2 the first of the means for adjusting the web winding conditions is web oscillator or steering

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frame guider 27 which is illustrated schematically. The web 23 first passes over an entry deflector roller 29 of guider 28, and passes vertically to a web entry roller 29, then horizontally to web exit roller 30. The 5 rollers 29¹ and 30 are mounted in a horizontally oriented guide frame 34 which is mounted for reciprocating pivotal movement in a horizontal plane on a vertical pivot axis A-A. Leaving exit roller 30, the web passes over exit deflector roller 32 toward 10 subsequent positions in the line.

The guide frame 28 can be reciprocally pivoted on axis A-A by conventional means, not shown in the drawing, to oscillate the path of the web as it moves toward the winding roll of the line. This is one 15 effective means known in the art for laterally offsetting thickened portions of the web as it is wound and thus reducing the tendency toward formation of hardstreaks in the wound roll. Because of the lateral movement imparted to the moving web by this oscillation 20 procedure, it is also referred to as "wobble winding" and "stagger winding." Selection of optimum oscillation parameters, i.e., amplitude and frequency, is desirable because if the film path is not offset sufficiently the hardstreak problem is not sufficiently reduced but if 25 the offset is too great the amount of edge waste that must be trimmed from the web is excessive.

One suitable apparatus for web oscillation is the web guiding apparatus disclosed in U.S. Patent No. 4,453,659, incorporated herein by reference. While 30 the patent describes the use of the apparatus to correct web deviations, it can also be used to cause sinusoidal lateral oscillation of the web. Another useful apparatus is disclosed in U.S. Patent No. 2,672,299, incorporated herein by reference.

35 After leaving the steering frame 28, the edges of the web 23 are trimmed by the edge slitters 33 and 34

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to remove edge waste caused by oscillation of the film and to form a straight edge.

Following the slitters 33 and 34, the web passes through another means for controlling winding conditions, namely, the knurling apparatus 35. This means, shown schematically in Fig. 2, includes two fixed wheels 36 and 37 positioned above web 23 and two adjustable wheels 39 positioned below the web. The web, optionally, is heated, e.g., ultrasonically as in U.S. Patent No. 4,247,273 (incorporated herein by reference) or otherwise, just before or during contact with the wheels. The wheels have patterned surfaces which, in known manner, are adapted to form thickened and knurled areas along the edges of the web. The edge thickness or knurl height depends upon the pressure applied by the adjustable wheels. This pressure is controlled in accordance with the invention by the control computer 27 to provide a knurl height which is sufficient to reduce hardstreak formation but is not so great as to cause the problems which are characteristic of excessively thickened edges.

After the knurling operation the web passes to a tension-controlling means 40. This comprises a fixed entry roller 41, a float roller 42 and a fixed exit roller 43. The force exerted by roller 42 to increase or decrease the web tension is also controlled in accordance with the invention by the control computer 27.

After passing the tension-controlling means, the web 23 is wound on the take-up roll or winder 45. Upon reaching this position the tension on the web has been controlled, the edge thickness has been controlled and the horizontal oscillation of the moving web has been controlled. These three conditions are controlled by the control computer 27. It determines from the thickness measurement by instrument 25 and from the

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input data as to film properties and defect tolerances, the conditions required to wind the web without exceeding defect tolerances.

Although Fig. 2 shows the control of the three winding conditions, web tension, edge thickness and the oscillation parameters of amplitude and frequency, it should be understood that it is not always necessary to adjust all three of these conditions. In particular, if defects can be sufficiently reduced by adjusting only the edge thickness and the web tension, it may be preferred to omit the web oscillator, since this operation causes edge waste. However, if lengthwise persistent widthwise thickness variations are so great that defects cannot be sufficiently reduced without using web oscillation, the method of the invention can include the control of that operation as has been described.

The output of the digital computer 27 which controls the steering frame 28 is ported through an electromechanical drive (e.g., a servo motor). The output of the computer 27 which controls the knurl thickness is ported to a pneumatic actuator in the tension float roll 42. Conventional digital to analog interfaces can provide the necessary output porting.

Fig. 3e of the drawing illustrates how the analytical model for predicting web imperfections is used in the method of the invention. The inputs to the model 50 are the average thickness profile 51, the web properties 52 and the initial winding conditions 53. As previously indicated, the average thickness profile can be derived by off-line measurements of a portion of the web or by on-line measurements during winding of the web. The web properties are as previously defined. The initial winding conditions include the web tension, the edge thickness (knurl height) and the oscillation amplitude and frequency.

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From these data the control computer executes the model as in Figs. 3a-3d and predicts the severity of web defects such as distortions, pressure damage to coated layers and blocking or adhesion of successive 5 laps of the roll. As indicated by decision block 54 of Fig. 3e, these predicted values are compared with the tolerances input as indicated by block 55. If the predictions are within tolerances (OK), the initial winding conditions input (block 53) are updated or 10 corrected (block 56) and used to control the winding tension, edge thickness and oscillation parameters for winding the roll 58, with the control means 40, 35 and 28 of Fig. 2.

If the predictions exceed tolerances, an 15 optimization routine (Block 60) is executed, preferably using linear programming techniques as discussed in the Press et al. text cited herein. This provides new values to update the winding conditions, as indicated by Block 62, which are used in winding of the next roll to 20 be produced. Thus, the measurements made for winding each roll are used to set the winding conditions for the next subsequent roll.

Figs. 3a-3e of the drawings illustrate the analytical model by means of which the method of the 25 invention is controlled. Definitions of the terms used in said figures are listed in Table I below. The algorithm where the pressure, stress and strain parameters are computed is set forth in the article by the inventor hereof which appeared in the TAPPI Journal 30 referenced below. The roll relaxation radii can be calculated using the polynomial extrapolation algorithm in the text by Press et al. referenced below. Both of these literature articles are incorporated herein by reference.

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Table IDefinitions:

- 8 $\rho(i, j)$ - widthwise roll radius distribution, where i designates the lap number within the roll, which can vary between 0 for the core and N at the outside of the roll and j designates widthwise position.
- 10
- R_0 - relaxation radius, which is the roll radius at which the tension in the length direction is zero.
- 15
- $c(j)$ - widthwise outside core radius distribution, where j designates widthwise position.
- 20
- N - number of laps in roll.
- M - number of widthwise locations.
- 25
- δ - width increment (web width divided by M).
- 25
- $\text{MIN} [\]$ - minimum value in a vector of values.
- $\text{EXC} [x, y]$ - $x-y$ for $x > y$.
- 30 0 otherwise
- $h(j)$ - average widthwise thickness profile, where j designates the widthwise location.
- 35

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Table I cont'd

	ϕ_1	- severity of pressure-induced winding imperfections.
5	S_1	- imperfection sensitivity function for pressure.
	ϕ_2	- same as ϕ_1 for tension.
10	S_2	- same as S_1 for tension.
	ϕ_3	- same as ϕ_1 for radial strain.
15	S_3	- same as S_1 for radial strain.
	ϕ_4	- same as ϕ_1 for tangential strain.
	S_4	- same as S_1 for tangential strain.
20	Φ	- imperfection severity function.
	C_k	- weight factor for <u>kth</u> imperfection.
25	ϵ	- tension tolerance.
	EXT	- polynomial extrapolation algorithm as described on pp. 80-83 of "Numerical Recipes, the Art of Scientific Computing" by V.H. Press et al., Cambridge University Press, 1986.
30		

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Table I cont'd

IRSN

- non-linear algorithm for predicting in-roll stresses as described by Z. Hakiel in "Non-Linear Model for Wound Roll Stresses", TAPPI Journal, Vol. 70, No. 5 pp. 115-117, May 1987.

5

10

Fig. 4 of the drawing is a plot of the average thickness distribution for a poly(ethylene terephthalate) film of nominal 0.007 in. thickness. The plot is obtained by thickness measurements with a contacting off-line LVDT based profiler, but could have been obtained with a "Beta-guage" instrument as previously described. Fig. 4 plots the thickness in mils (0.001 in.) as the vertical axis against the widthwise locations. As the plot shows, at both edges the film is thicker than 7.5 mils, thus, identifying the presence of knurled or thickened edges. At intermediate points across the web, the average thickness varies from as low as about 6.9 mils to as high as about 7.3 mils.

Figs. 5, 6, 7, and 8 are predicted plots of roll diameters, the predictions being made by use of the analytical model of Figs. 3a-3d.

The following tables list the characteristics of the web and roll (Table II) as well as winding tension and knurl height (Table III) for the four predicted cases depicted in the plots of Figs. 5-8.

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Table II

5	Web width	54 in.
	Web thickness	0.007 in.
	Knurl width	0.5 in. at each edge
	Core diameter	5 in.
	Roll diameter	15 in.
10	Elastic modulus of web	660,000 lb/in ²
	Poisson's ratio of web	0.3

Table III

	<u>Fig.</u>	<u>Winding Tension (lb.)</u>	<u>Knurl Thickness (in.)</u>
15	5	200	0.0073
	6	110	0.0073
	7	200	0.0075
20	8	110	0.0075

Fig. 5 shows the roll profile at successive roll radius during winding. Initially at 2.5 in. radius, the roll has a typically uneven profile such as in Fig. 4. Then as the roll is wound at a winding tension of 200 lb. and with the film having a knurl height of 0.0073 inch at each edge, the roll surface progressively begins to develop hardstreaks. When the roll radius has reached 7.5 in. (the uppermost plot of Fig. 5) two severe hardstreaks A and B are apparent.

The flat portion of this plot and others in Figs. 6-8, represent the relaxation radius, R_0 , of the roll.

Fig. 6 plots the predicted roll profile at successive stages for a roll being wound at a lower winding tension of 110 lbs and having a knurl height as in Fig. 5, namely, 0.0073. Again as in Fig. 5, at a radius of 2.5 inches, the roll has the typical surface variations exhibited in Fig. 5. As winding proceeds and

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the roll radius increases to 7.5 inches, (the uppermost plot) two smaller hardstreaks than in Fig. 5, develop in the roll.

Fig. 7 is a similar series of plots for a roll being wound at 200 lbs tension but with greater knurl height, i.e., 0.0075 inch. The traces progressing from bottom to top (from 2.5 to 7.5 inches) show a radius steadily improving surface regularity. At 7.5 inches the hardstreak is barely noticeable.

Fig. 8 is another series of such plots for a roll being wound at 110 lbs. tension and with a greater knurl height, i.e. 0.00075 in. Under these conditions, at 7.5 inches, the roll is essentially free of hardstreaks.

Although the invention has been described specifically with reference to the winding of a melt-cast poly(ethylene terephthalate) web, it should be understood that the method can be used for controlling and reducing the formation of hardstreaks in the winding of a wide range of plastic webs. Other melt cast polymeric webs such as polyolefins are examples, as well as solvent-cast webs such as cellulose esters and especially cellulose triacetate.

This invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

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CLAIMS

- 1 1. The method of winding on cores plastic webs having thickened edges which comprises:
- measuring properties of a web to be wound on a core including:
- 5 (a) modulus of elasticity of the plastic,
(b) stack-wise compression modulus of the web,
(c) stack-wise compression modulus of the thickened edges,
- 10 (d) Poisson's ratio of the plastic,
(e) stress relaxation modulus of the web,
selecting initial winding conditions for
(a) initial web tension,
(b) initial edge thickness, and
15 (c) initial web oscillation;
iteratively measuring widthwise thickness variations of said web at lengthwise locations on the web,
averaging the measured widthwise thickness
20 variations in the lengthwise direction to obtain an average widthwise thickness distribution for the web,
measuring the core modulus and the width and diameter of the core,
predicting the severity of winding
25 imperfections from the relationship of (1) said properties, (2) the average widthwise thickness distribution of the web, (3) the initial winding conditions and (4) said measurements of the core,
comparing the predicted imperfections with
30 predetermined tolerances to determine whether the imperfections are within or exceed the tolerances;
when said predicted imperfections are within the tolerances, winding the first web on a core at said initial winding conditions; and

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35 when said predicted imperfections exceed the tolerances, winding the web on the core under corrected winding conditions for at least one of web tension, edge thickness and web oscillation.

1 2. The method according to claim 1 wherein the severities of winding imperfections, Φ , are predicted by means of the analytical model of Figs. 3a and 3b, the parameters of which are defined in Table I.

1 3. The method according to claim 1 which comprises winding a second web at initial winding conditions corresponding to the corrected values for the first web.

1 4. The method according to claim 1 wherein said measurements are collected upon winding of a first web on said core, said winding conditions are then computed based upon the collected measurements and a second web is wound on said core under said computed winding conditions.

1 5. The method according to claim 1 wherein said averaging, predicting and winding condition establishing steps are carried out with the aid of a digital computer.

SUBSTITUTE SHEET

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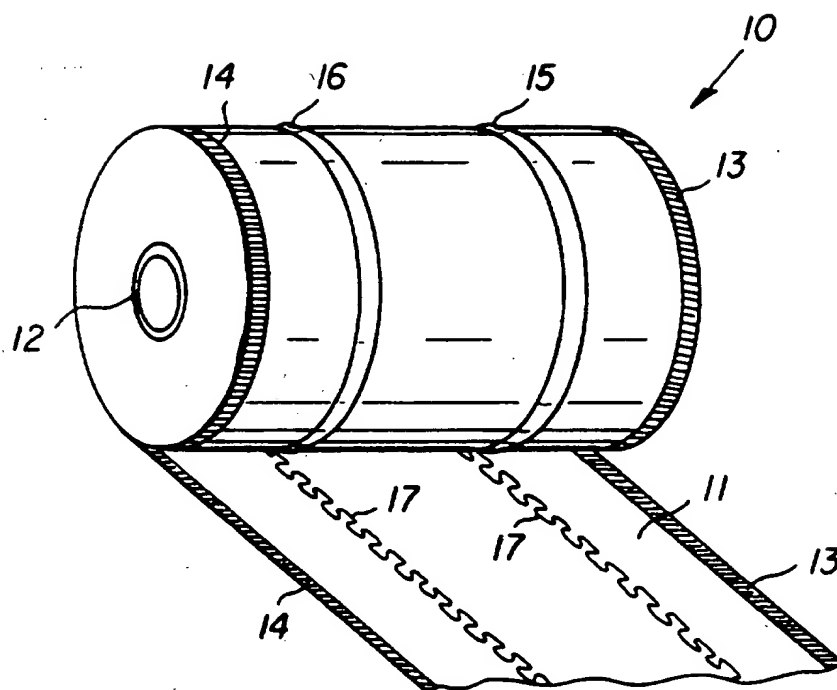
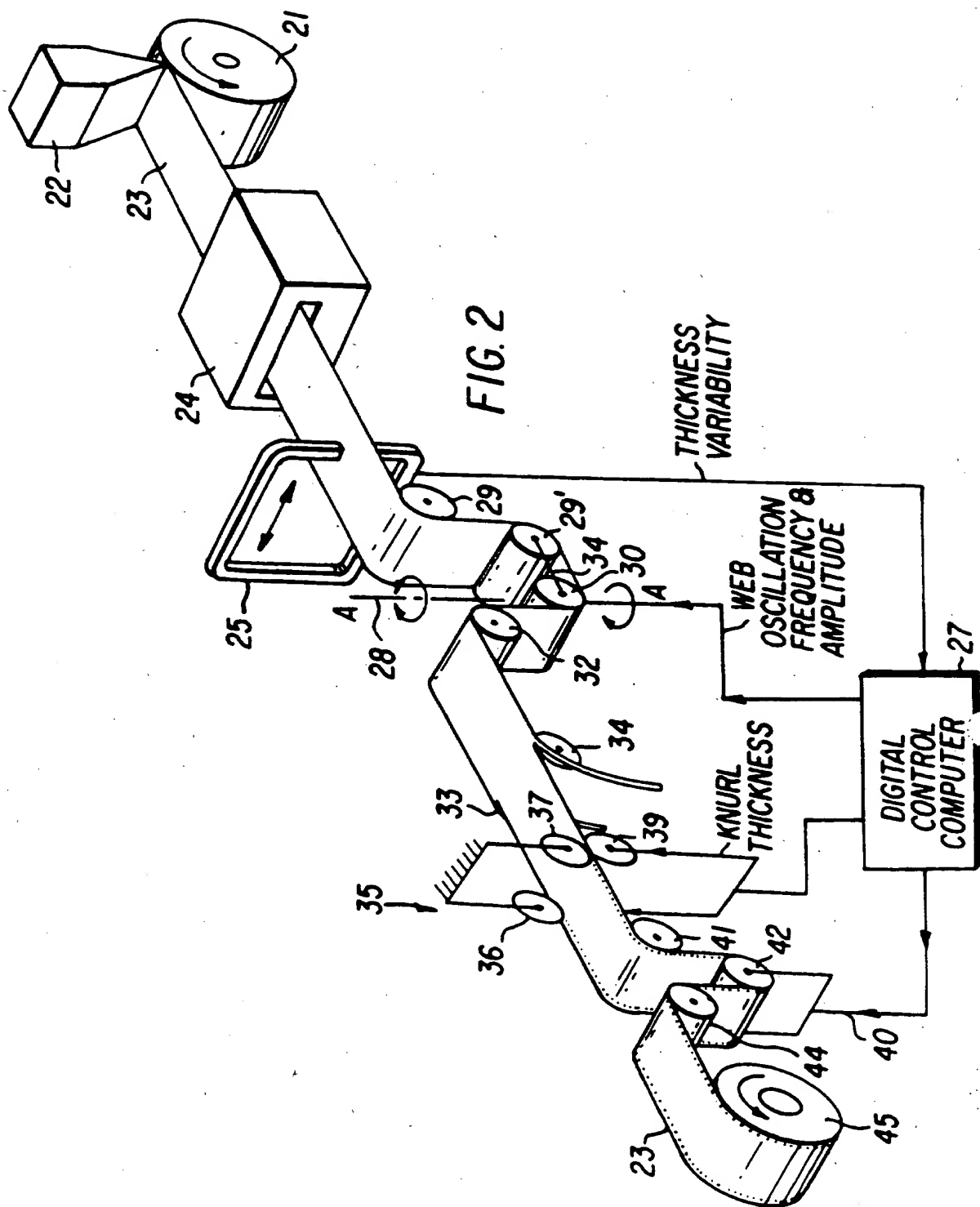


FIG. 1

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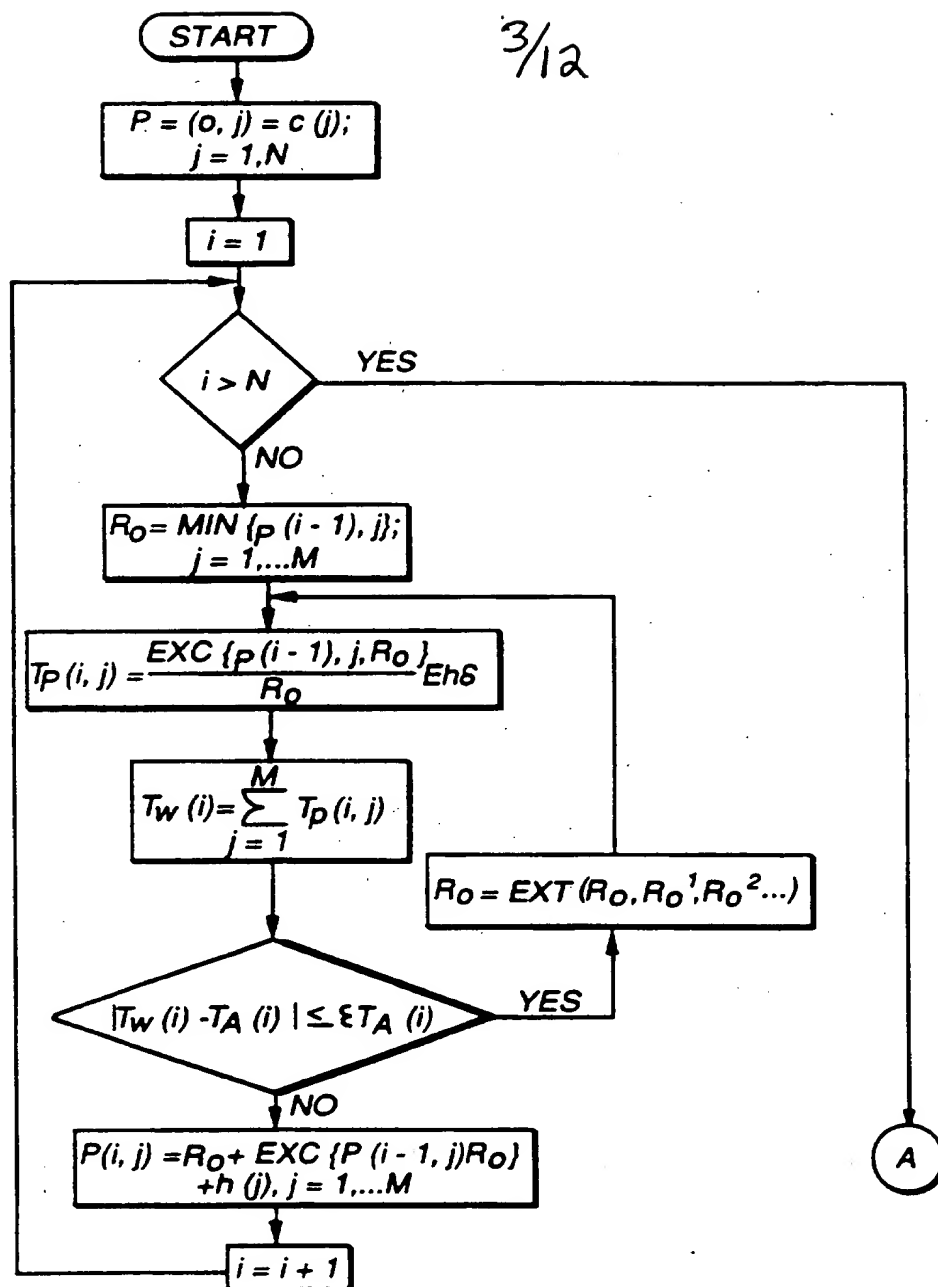


FIG. 3A

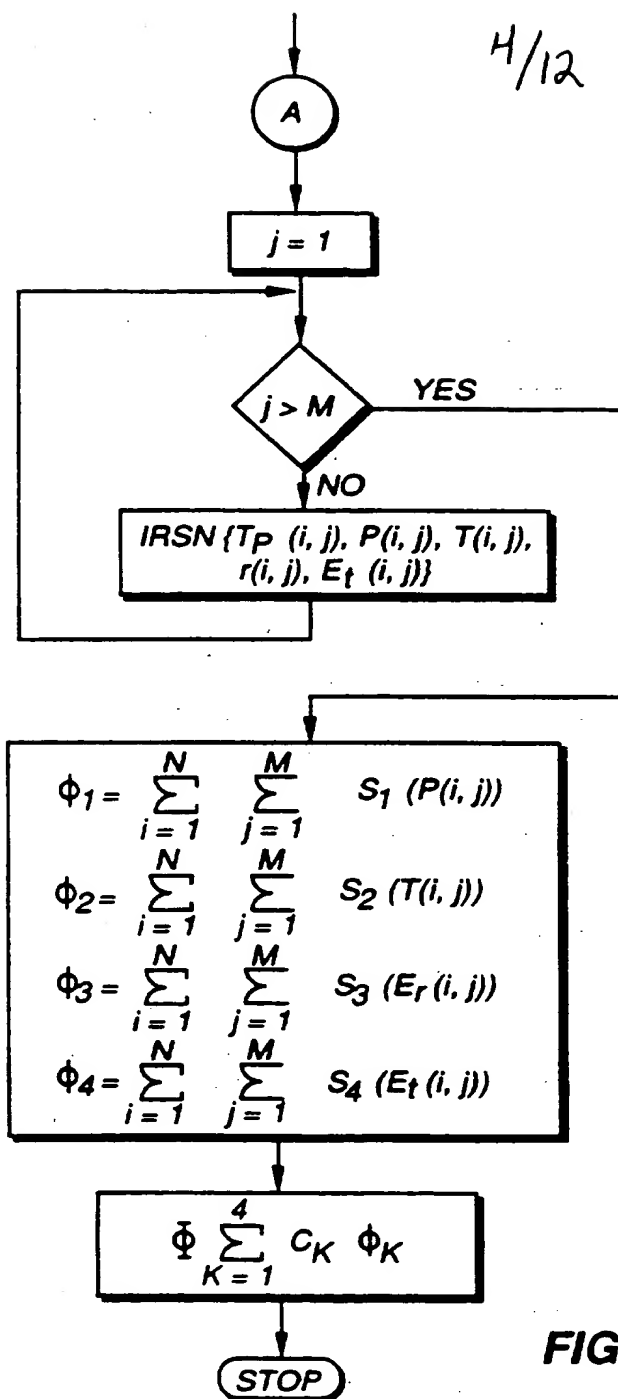


FIG. 3B

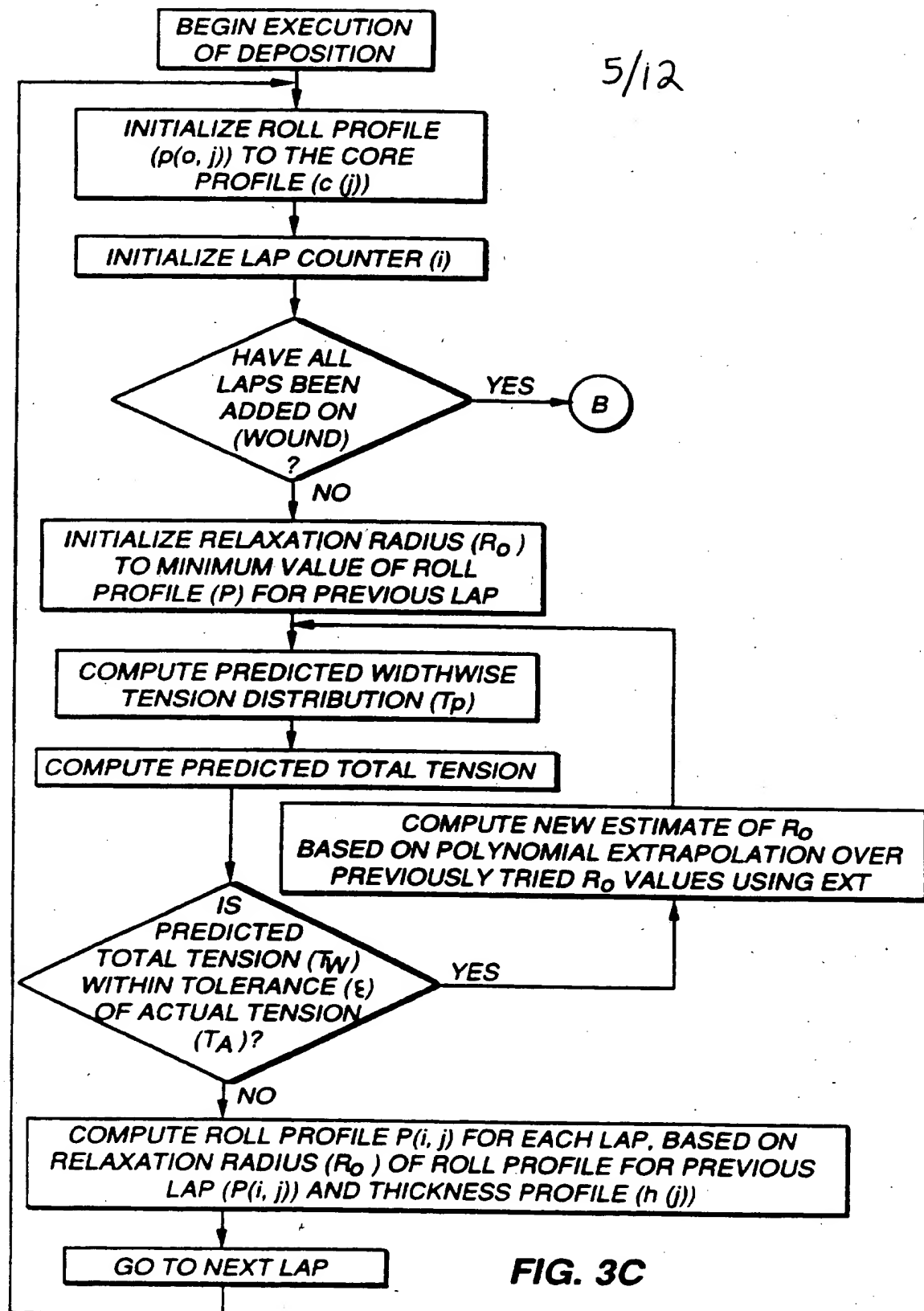


FIG. 3C

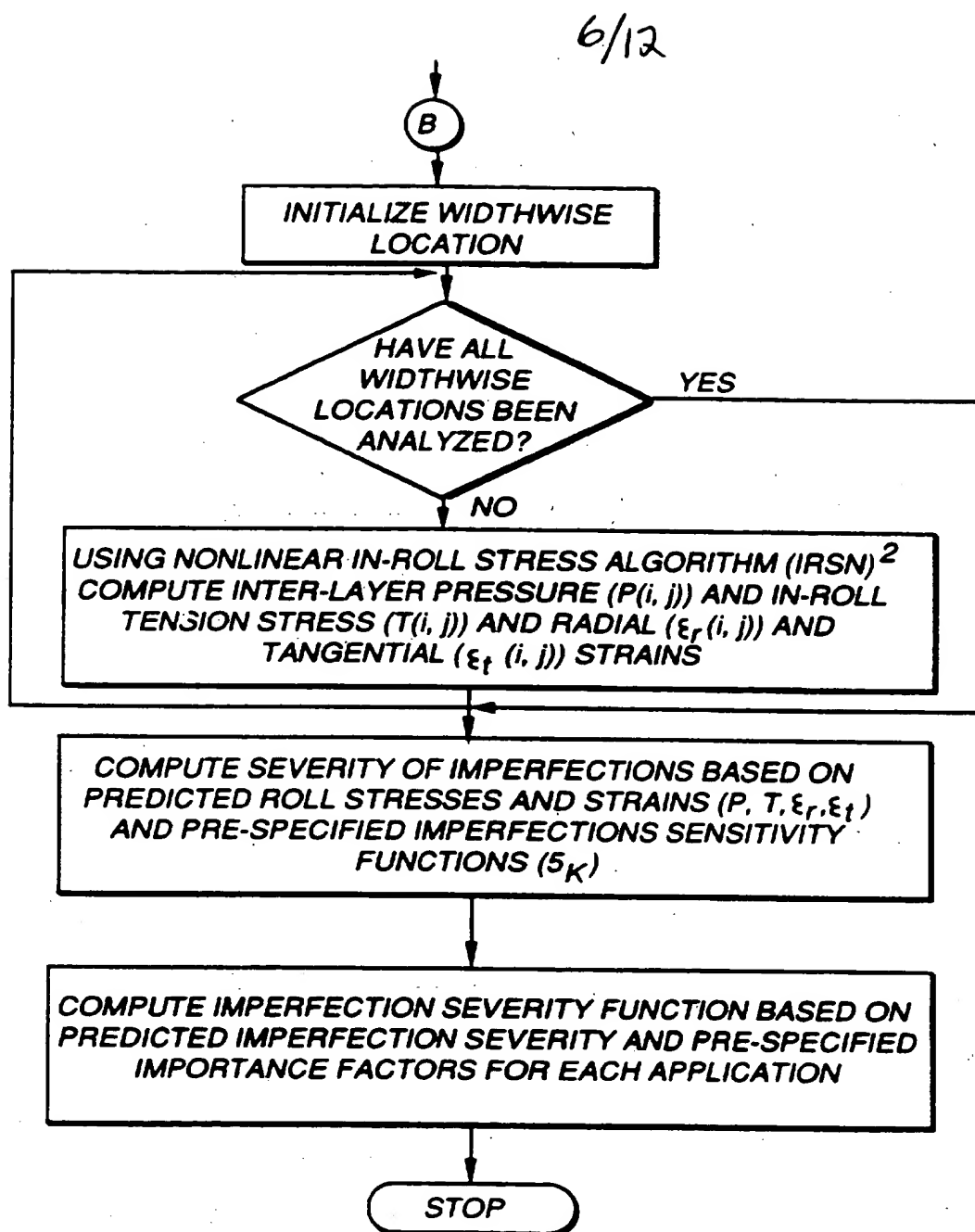
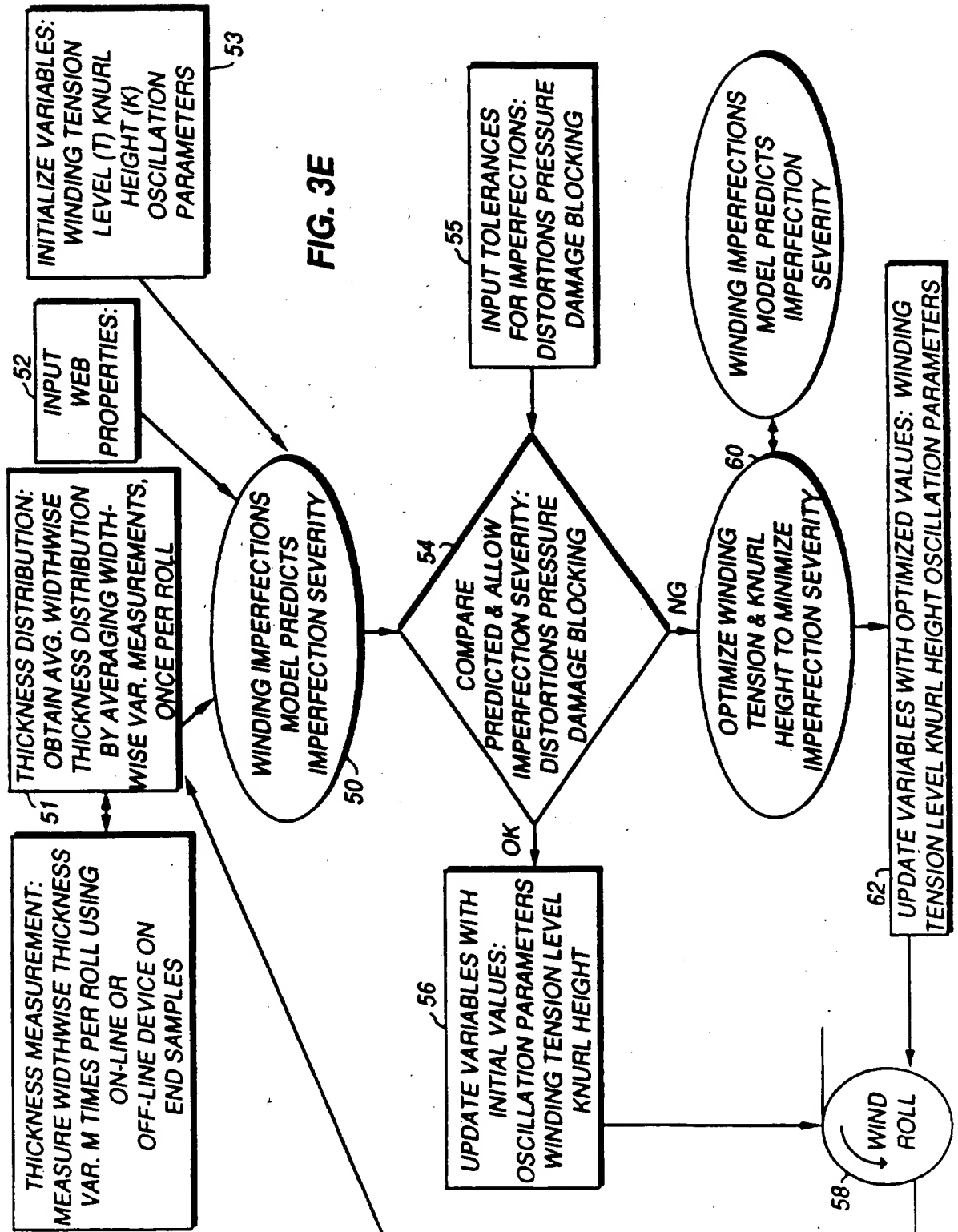


FIG. 3D

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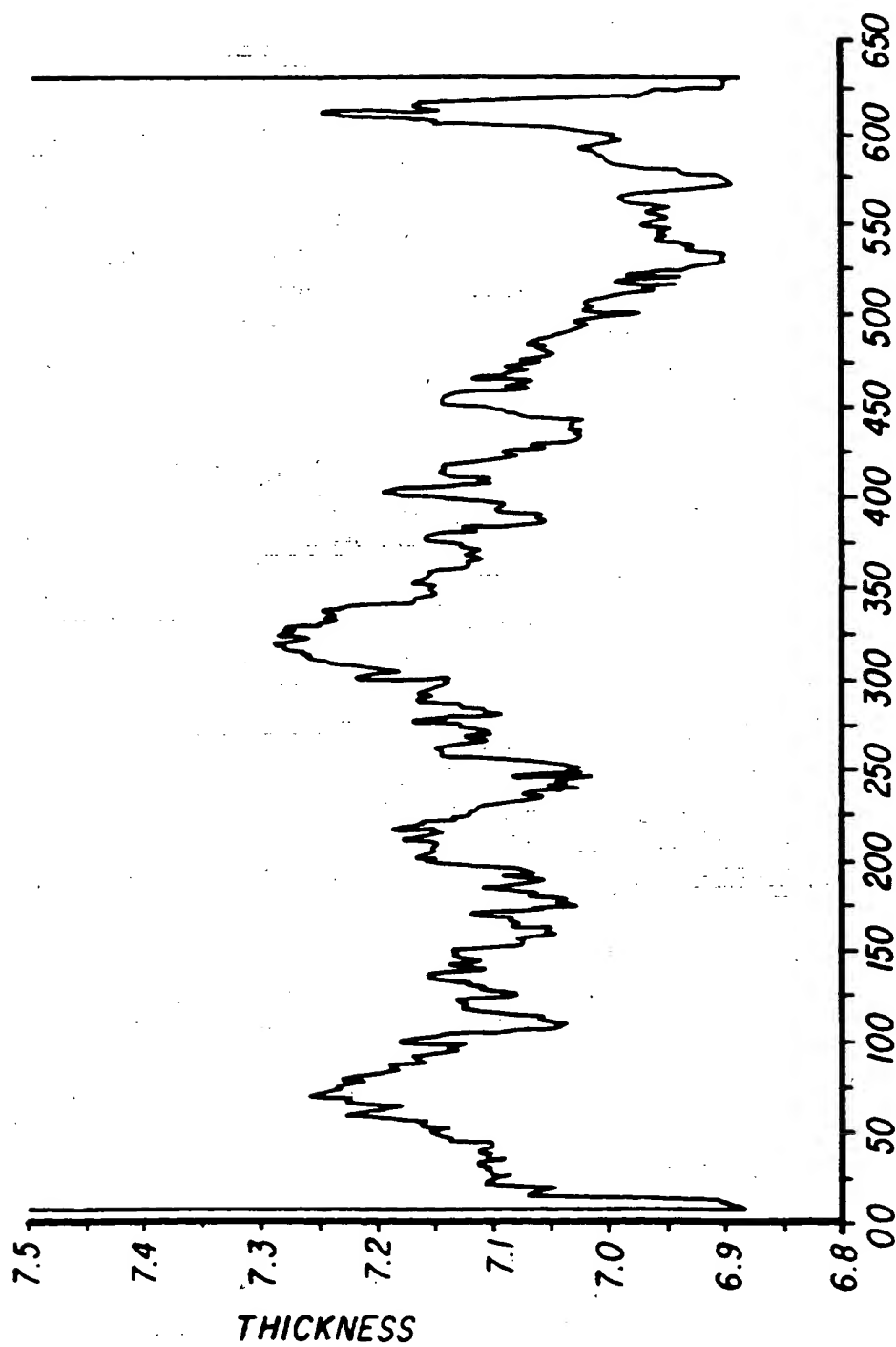
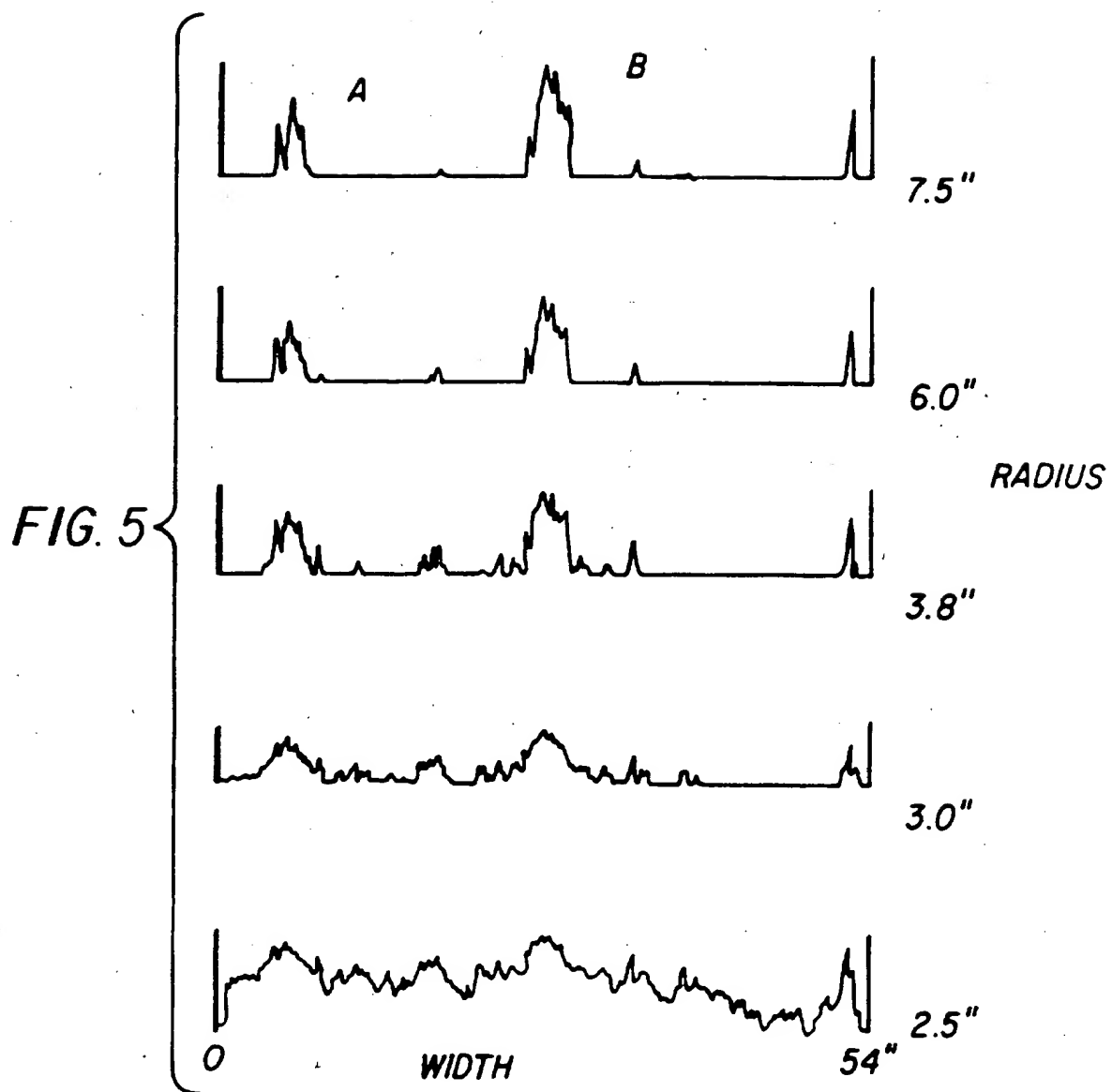
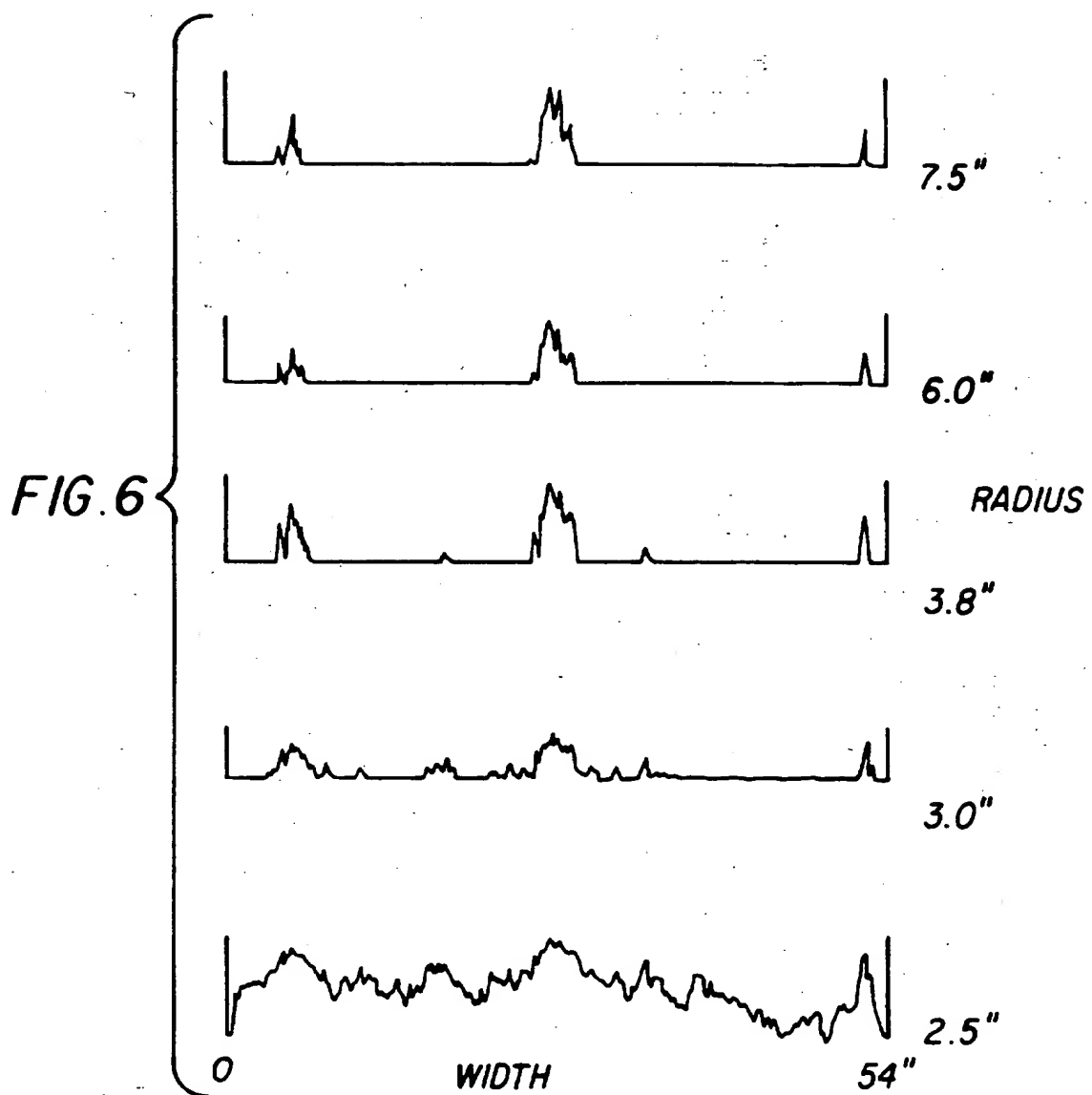


FIG. 4

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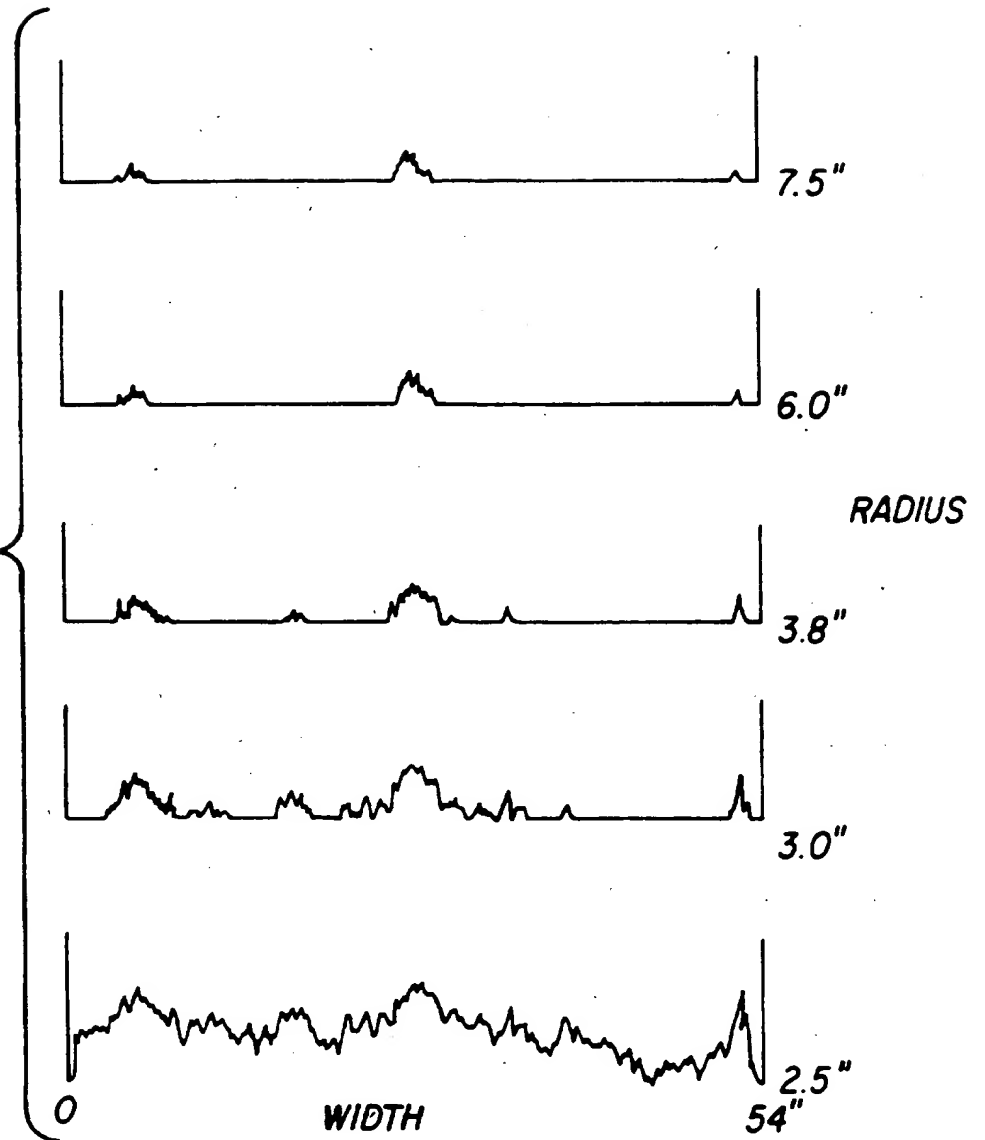


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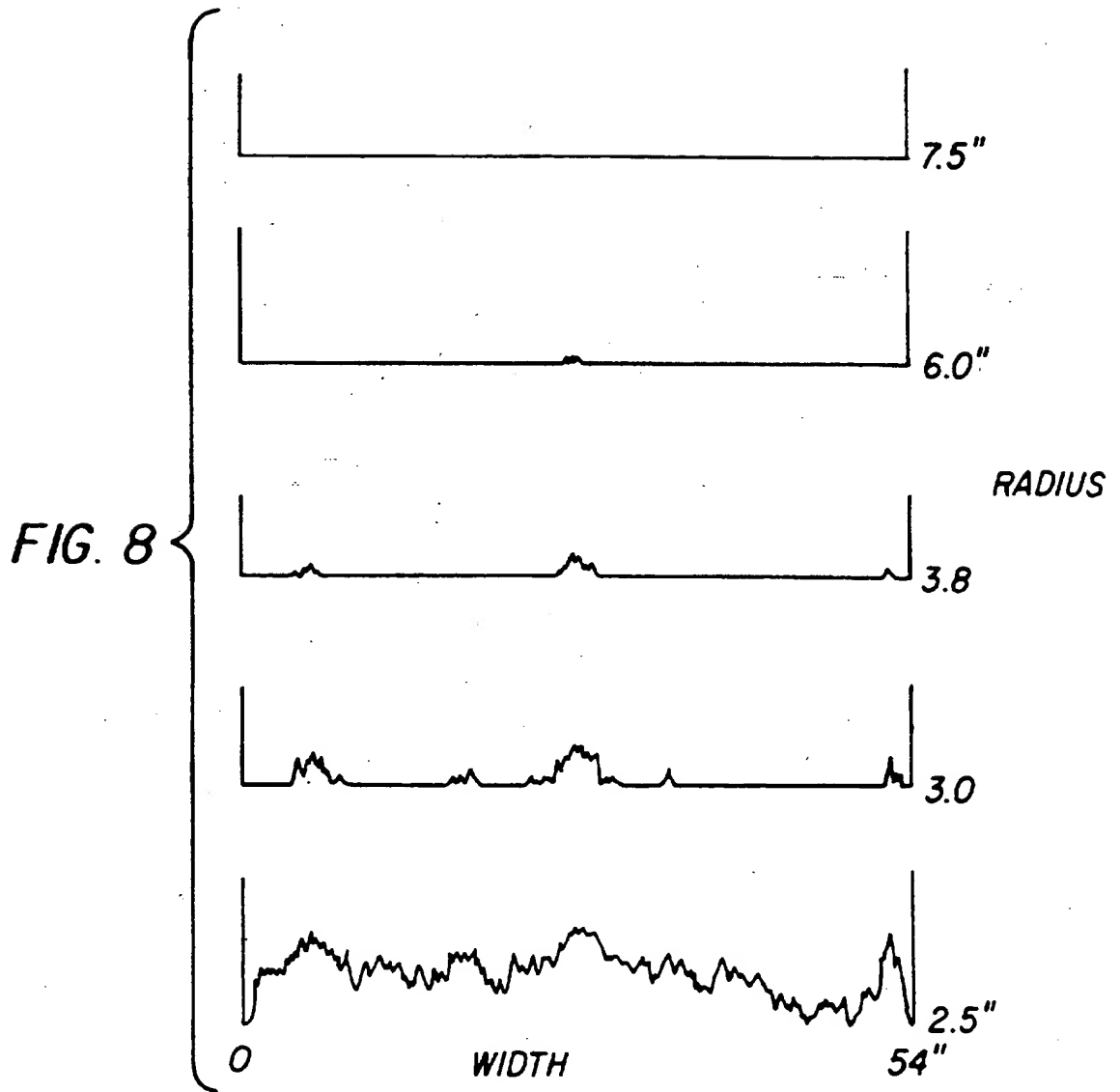


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FIG. 7



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INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 92/03525

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC Int.Cl. 5 B65H26/02																	
II. FIELDS SEARCHED <div style="text-align: center; border: 1px solid black; padding: 2px;">Minimum Documentation Searched⁷</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%; border: 1px solid black; padding: 2px;">Classification System</td> <td style="border: 1px solid black; padding: 2px;">Classification Symbols</td> </tr> <tr> <td style="border: 1px solid black; padding: 2px;">Int.Cl. 5</td> <td style="border: 1px solid black; padding: 2px;">B65H</td> </tr> </table> <div style="text-align: center; border: 1px solid black; padding: 2px;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched⁸</div>			Classification System	Classification Symbols	Int.Cl. 5	B65H											
Classification System	Classification Symbols																
Int.Cl. 5	B65H																
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹ <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; border: 1px solid black; padding: 2px;">Category *</th> <th style="width: 70%; border: 1px solid black; padding: 2px;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 20%; border: 1px solid black; padding: 2px;">Relevant to Claim No.¹³</th> </tr> <tr> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="border: 1px solid black; padding: 5px;"> US,A,4 535 950 (INTERNATIONAL PAPER COMPANY) 20 August 1985 see column 5, line 27 - column 7, line 13; claims 8,9; figures 1,3,4 --- </td> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">1</td> </tr> <tr> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="border: 1px solid black; padding: 5px;"> PATENT ABSTRACTS OF JAPAN vol. 8, no. 274 (M-345)14 December 1984 & JP,A,59 143 837 (FUJI TEKKOSHO K.K.) 17 August 1984 see abstract --- </td> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">1,5</td> </tr> <tr> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="border: 1px solid black; padding: 5px;"> TAPPI. vol. 62, no. 10, October 1979, ATLANTA US pages 83 - 85; PFEIFFER D.: 'PREDICTION OF ROLL DEFECTS FROM ROLL STRUCTURE FORMULAS' see abstract --- </td> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">1</td> </tr> <tr> <td colspan="3" style="border: 1px solid black; padding: 5px; text-align: center;"> --- -/- </td> </tr> </table> <div style="font-size: small; margin-top: 10px;"> <p>* Special categories of cited documents : ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"A" document member of the same patent family</p> </div>			Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	A	US,A,4 535 950 (INTERNATIONAL PAPER COMPANY) 20 August 1985 see column 5, line 27 - column 7, line 13; claims 8,9; figures 1,3,4 ---	1	A	PATENT ABSTRACTS OF JAPAN vol. 8, no. 274 (M-345)14 December 1984 & JP,A,59 143 837 (FUJI TEKKOSHO K.K.) 17 August 1984 see abstract ---	1,5	A	TAPPI. vol. 62, no. 10, October 1979, ATLANTA US pages 83 - 85; PFEIFFER D.: 'PREDICTION OF ROLL DEFECTS FROM ROLL STRUCTURE FORMULAS' see abstract ---	1	--- -/-		
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IV. CERTIFICATION <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border: 1px solid black; padding: 5px;"> Date of the Actual Completion of the International Search <div style="text-align: center;">14 SEPTEMBER 1992</div> </td> <td style="width: 50%; border: 1px solid black; padding: 5px;"> Date of Mailing of this International Search Report <div style="text-align: center;">24. 09. 92</div> </td> </tr> <tr> <td style="border: 1px solid black; padding: 5px;"> International Searching Authority <div style="text-align: center;">EUROPEAN PATENT OFFICE</div> </td> <td style="border: 1px solid black; padding: 5px;"> Signature of Authorized Officer <div style="text-align: center;">THIBAUT E.E.G.C. </div> </td> </tr> </table>			Date of the Actual Completion of the International Search <div style="text-align: center;">14 SEPTEMBER 1992</div>	Date of Mailing of this International Search Report <div style="text-align: center;">24. 09. 92</div>	International Searching Authority <div style="text-align: center;">EUROPEAN PATENT OFFICE</div>	Signature of Authorized Officer <div style="text-align: center;">THIBAUT E.E.G.C. </div>											
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	<p>TAPPI. vol. 58, no. 8, August 1975, ATLANTA US pages 152 - 155; MONK D.W., LAUTNER W.K., MCMULLEN J.F.: 'INTERNAL STRESSES WITHIN ROLLS OF CELLOPHAN' See page 152, paragraph : "calculation of radial compressive pressure and circumferential film tension" See page 155, paragraph: "Conclusions"</p> <p>---</p>	1

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